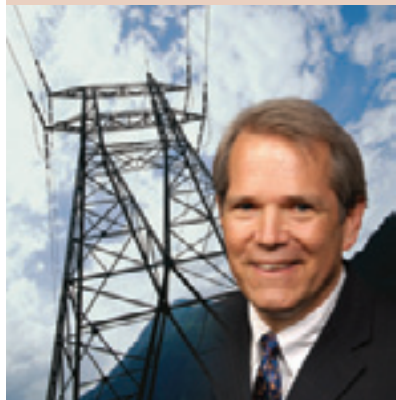


“Energy underpins our national security, economic prosperity, and global stability. Any interruption in the steady supply of electrical power, oil, or gas in the U.S. could have a crippling effect on our national security.”



Water is also a key factor in global stability. Tied closely, too, are the supporting critical infrastructures that assure water and energy supply. The goal of Sandia's Energy and Infrastructure Assurance program is to enhance the safety, security, and reliability of energy and water through the application of science and technology. Sandia is providing solutions to the complex problems of supplying the nation with clean, abundant, and affordable energy and water.”

Les Shephard

*Vice President
Energy and Infrastructure
Assurance*

Enhancing the Safety, Security, Reliability of our Energy and Water

Energy, water, and security enabled by technology

It's no secret. While world resources are sufficient to satisfy demands for energy and water in the foreseeable future, challenges abound. They include environmental problems, political concerns, distribution of resources, and a myriad of other issues. Internationally, the relative scarcity of energy and water is a barrier to raising prosperity and a desta-

expertise to ensure those infrastructures remain secure and reliable.

Energy efficiency and renewable/fossil energy

Sandia has a long track record of providing assistance to the U.S. energy sector. Since the oil embargo of 1973, Sandia has recognized the link between secure and abundant energy and our national security. Sandia continues to develop



Sandia is joining forces with Stirling Energy Systems of Phoenix to build and test six new solar dish-engine systems like this one. Each system will provide enough solar electricity to power more than 40 homes.

bilizing influence. At home, the generation and delivery of these key resources require a vast inter-related network of circuits, wires and cables, pipelines, information, and services—all part of the nation's critical infrastructures. Sandia is at work to develop technologies and

technologies to boost production in petroleum, hydroelectric, geothermal and solar power, nuclear fission, and fusion. We continue to work with the oil industry to develop more efficient means of producing and extracting fossil fuels, using our knowledge of exploration

technologies and reservoir-management practices. Sandia is taking a new approach as drilling reaches deeper and deeper to tap new gas and oil reserves, extending our high-temperature drilling technology developed in the geothermal industry. This effort involves bit design improvements, down-hole electronics, diagnostics-while-drilling technologies and broadband borehole telemetry systems.

Sandia and petroleum explorationists in Southeast New Mexico and West Texas have teamed on a three-year project to develop geophysical mapping and computer simulation tools to identify new reserves on the Central Basin Platform. A Texas study estimates potential reserves in the area as high as five billion barrels, straddling the two states. The relatively small and deeply buried reserves aren't detectable by conventional seismic techniques. Sandia researchers are applying mathematical approaches to the seismic data to better identify rocks with reservoir potential.

Sandia continues in the role of science and engineering advisor to the DOE's Strategic Petroleum Reservoir. This reserve, in 60 salt caverns along the Gulf Coast, helps ensure oil supplies during the nation's war on terrorism and in response to other threats. Sandia supplies the geotechnology and engineering needed to fill and update the existing facilities and to lay the foundation for potential future expansion. Further offshore we are working with a consortium of deepwater producers to model and manage issues relating to stability of deep wells, a new frontier for domestic production.

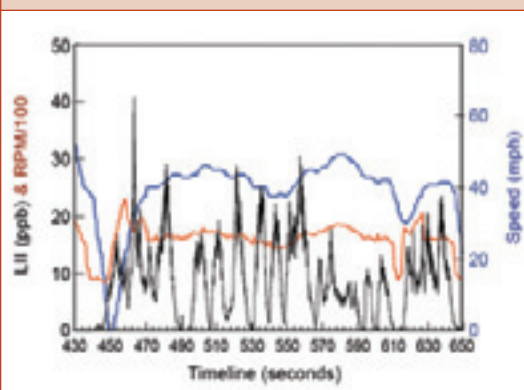


Sandia's Richard Steeper and Amelia Fayoux, of Peugeot-Citroen, at work in Sandia's Combustion Research Facility at the optically accessible single-cylinder HCCI engine.

Given that 85 percent of our nation's energy is produced by combustion, the design of more efficient, less-polluting combustion devices continues to be a national priority. At the Combustion Research Facility (CRF) in California, Sandia has studied ways to increase the efficiency and decrease the emissions of combustion sources, especially with diesel engines. In the years since its inception in 1979, CRF has become recognized as a world leader in state-of-the-art measurement and computational tools for application to combustion. Recent research includes:

- The 2007 EPA regulations for both light- and heavy-duty vehicles call for significant reductions in particulate matter emissions. To meet these requirements, industry has a critical need for new instrumentation capable of real-time measurements with high sensitivity.

Emissions data captured by LII method compared to engine speed (red) and vehicle speed (blue) shows that fuel injection cycled on and off during this coasting descent.



Research team for evaluation of laser induced incandescence (LII) for measurement of real-time air emissions.

Sandia's collaborative effort with the National Research Council Canada and Artium Technologies has led to Artium's development of a commercial instrument using laser-induced incandescence. The technology has been evaluated at test facilities at Ford and Cummins and on-board a diesel passenger car in collaboration with Chevron-Texaco.

■ A new laboratory that allows researchers to study a promising new combustion concept for ultra-low emission, high efficiency engines came on line. The laboratory houses a single-cylinder automotive scale engine with extensive optical access. Researchers can use advanced

optical diagnostics to study combustion occurring inside the cylinder. Called the Homogeneous Charge Compression Ignition engine, this alternative piston-engine can rival the high efficiency of diesel engines with low levels of nitrous oxides and particulate emissions.

■ Sandia joined with four other national laboratories and 10 automotive engine manufacturers in an agreement to better focus research on a next-generation of efficient, clean engines. Research will investigate in-cylinder mixing, combustion, and emission processes relevant to advance engines. Conventional, non-petroleum, and hydrogen fuels will be included in the effort.

Sandia Center of Excellence for Hydrogen

Hydrogen is the dream fuel of the future. The DOE has selected Sandia to lead a virtual Center of Excellence for the development of reversible metal hydrides materials. A key objective will be to develop a class of materials capable of storing



hydrogen safely and economically aboard a vehicle that can run for at least 300 miles before refueling. The virtual center consists of eight universities, four other national laboratories, and three industrial companies. Sandia is serving as lead laboratory and coordinator of research and development. It will undertake \$30 million of research and development over the next five years. Additionally, we have been assigned the responsibility to provide the science needed to draft domestic and international codes and standards for hydrogen commercialization.

Energy research shows technological promise

Sandia's California site established the Distributed Energy Technologies Laboratory (DETL) to assist in the development and implementation of distributed energy resources. DETL tests microturbine, engine-generator, photovoltaic, fuel cell, and energy-storage technologies both individually and in a collective microgrid. Collaborators include manufacturers, utilities, DOE, DoD, the California Energy Commission, universities, standards organizations, and other national and private laboratories. Energy security is one of several important benefits that distributed energy resources will offer to the nation's electric power infrastructure.

Already, the DOE and the California Energy Commission are supporting integration of distributed resources into the energy infrastructure. Sandia is a member of a partnership to develop this integration. Our information technology and data visualization experts are developing a real-time control system to help electric system

operators monitor voltage and frequency across the grid. At the same time secure communications and control technologies are also being developed to reduce vulnerability of the nation's electric system to cyber threat.

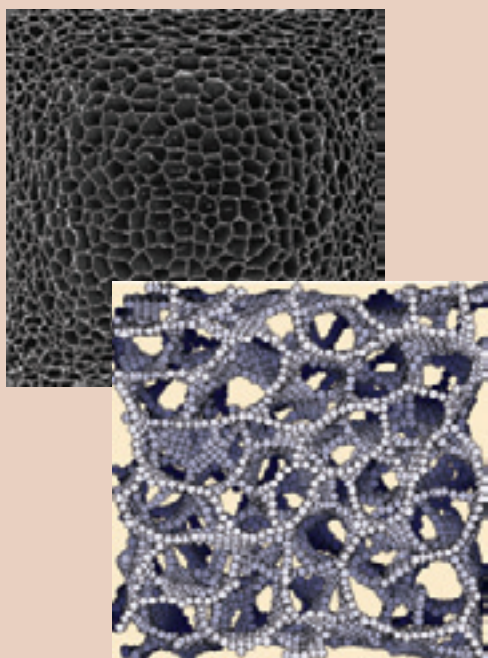
Sandia is working with industry, academia, and government to establish a national research initiative in solid-state lighting—the Next-Generation Lighting Initiative. Solid-state lighting uses light emitting diodes that are potentially as much as 10 times more efficient than incandescent and twice as efficient as fluorescent lamp technologies. Although not yet proven in all wavelengths, these diodes offer greater versatility and a longer lifetime. Sandia has completed editing a DOE Technology Roadmap for this important project.

Nanoscience: for energy and the environment

DOE Office of Science research has shown that nanotechnologies have great promise for innovative materials that will positively impact our energy and environmental problems.

The Office of Science funds many Sandia energy research projects. Nanotechnologies hold great promise, just as in Sandia's other mission areas. Construction began on the Center for Integrated Nanotechnologies, jointly operated by Sandia and Los Alamos national laboratories. The center will provide tools and expertise for integrating the world of nanoscale materials and devices with other technology scales. This expertise will be available "outside the fence" to university, industry, and government laboratory researchers.

A number of advances have already been made. By directing the assembly of nanoparticles in suspensions by the application of magnetic and electric fields, Sandia scientists have created not a single class, but classes of tailorable materials that have no counterparts in nature. These materials have strongly enhanced magnetic, dielectric, mechanical and thermal properties. Once assembled, the suspensions are polymerized to freeze the structures.



A composite structure formed by a triaxial magnetic field. We have demonstrated the use of these composites in ultra-sensitive chemical, stress, temperature and motion sensors, actuators, and super capacitors.

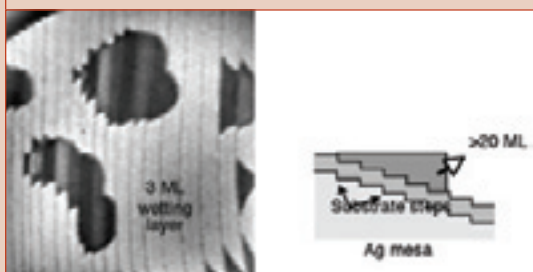
The work has combined experiments, theory, and simulations in novel ways and is receiving high recognition for its originality and innovativeness. Sandia has demonstrated the use of these composites in ultra-sensitive chemical, stress, temperature and motion sensors, and in actuators and supercapacitors. Other novel applications include tamper-proof, two-level

memories, artificial muscles, filtration membranes, super-magnetostrictive or -electrostrictive elements, particle patterning, and microfluid stirring.

Sandia is using engineered defects and newly developed analytical techniques to unravel the mysteries of how localized corrosion begins in aluminum. We are generating mechanistic information by comparing the characteristics of nanometer-length scale degradation processes in synthesized protective oxide structures with those in actual alloy systems. This knowledge is a critical component in our ongoing effort to develop predictive models of materials aging.

Through low-energy electron microscopy (LEEM) observations, we have discovered a fundamentally new mechanism by which thin films can “de-wet” their substrate. A long-standing mystery has been how thin film islands can thicken upon de-wetting since there is a large energy barrier to creating new surface steps. Our experiments have shown that thin film islands can avoid this barrier by moving laterally down a “staircase” of atom-high substrate steps. This entirely unanticipated result suggests strategies by which nanoscale thin film islands may be controlled by manipulating the density of atomic-scale steps in the underlying substrate.

Researchers also used the LEEM real-time imaging technique to analyze how a surface of reactive titanium oxide responds when the ambient oxygen concentration is varied. Increasing the oxygen pressure caused atomic steps on the surface to advance. The crystal grew when the gas-



Low-energy electron microscope images like this one have suggested strategies by which nanoscale thin films may be controlled by manipulating the density of atomic-scale steps in the underlying substrate. Shown are silver film islands on a stepped ruthenium substrate.

phase oxygen reacted with excess titanium stored in the form of interstitials. Quantitative analysis revealed that the local rate of crystal growth was strictly proportional to the local length of steps. That is, crystal growth only occurs when oxygen reacts with titanium near a step.

In cooperation with our Science, Technology and Engineering unit, the Genomes to Life (GTL) project is developing computational methods and capabilities to advance understanding of more complex biological systems and predict their behavior. The Sandia-led GTL project includes participants from four DOE laboratories, three universities, and four institutes with diverse backgrounds ranging from biology to physics to mathematics. The goal of the project is to better understand carbon-fixing microorganisms in the ocean and their response to man-made increases in carbon pollution.

The water initiative

Global scarcity of fresh water and subsequent instability are being described as the next great flashpoint, much like the role oil played in the 20th century. Sandia's water-management initiative seeks solutions to the challenges facing our nation's water infrastructure—challenges of scarcity, systems vulnerability, quality, and the economics of supplying drinkable water.

The initiative focuses on monitoring water quality, assessing infrastructure security, providing treatment technologies, and supporting international cooperative water management. These areas of concern are addressed through a variety of programs. Sandia, in cooperation with the American Water Works Association Research Foundation and the EPA, developed security risk-assessment methodology for assessing the surety of water utilities. This water infrastructure assessment tool has been employed to evaluate security and mitigate risks at more than 90 percent of



The dark bands are atomic steps on a TiO_2 surface as observed by low-energy electron microscopy. The closed islands are spawned from the two dislocation spirals. Field of view is 5 mm



The Tularosa Basin National Desalination Research Facility in Alamogordo, now in the early stages of construction, will be a focal point for advanced research projects. Sandia worked with the Bureau of Reclamation to develop a conceptual design for the facility.



the largest U.S. cities, serving an estimated 130 million consumers.

Purification of Earth's saline water (more than 97 percent of this planet's water) could provide relief to a growing demand for fresh water that already outstrips supply in many parts of the world. Sandia, in cooperation with the U.S. Bureau of Reclamation, has taken a two-pronged approach: 1) a research and development roadmap defining a path through the year 2020 that will support solving our water supply-related needs by advancing water desalination technology; and 2) building of a research facility in Alamogordo, New Mexico, in the Tularosa Basin, to test and evaluate novel desalination technologies. Now under construction, the 16,000-square-foot facility will be a national center for research that involves the removal of salts in brackish ground water. The facility will also look at the use of renewable energy, such as solar and wind, for water treatment.

Community-based management of water resources is a key to using every drop wisely. Sandia has developed a dynamic simulation model of the hydrology, demography, and economy in the Middle Rio Grande Basin and applied it to helping stakeholders understand the ramifications of trade-off decisions, from choosing crops to providing water for the endangered silvery minnow. Our cooperative modeling process bridges the technical demands and capabilities of a rigorous, quantitative model and the collaborative social processes required for community-based management. For researchers the next step is extending the use of this valuable tool to help resolve regional and international water disputes around the globe.

The global nuclear future

As the world comes to grips with the energy challenges of the 21st century, it becomes clear that nuclear power will be vital to the global energy future. To regain U.S. leadership in the energy field, an integrated energy, nuclear leadership, and national security policy must be developed, recognizing inter-relationships between all aspects of nuclear energy and our national security.

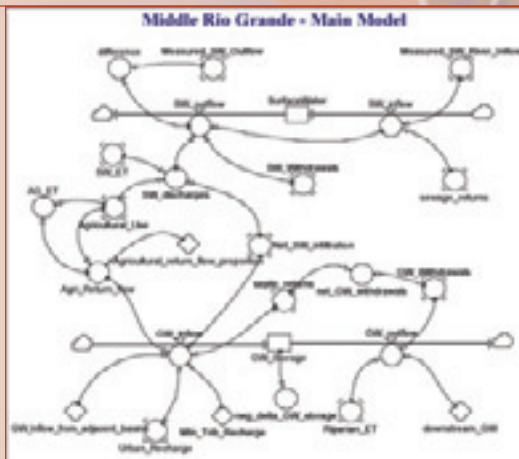
"Global Nuclear Future" is a Sandia vision, now shared by many others, about how nuclear energy can serve our requirements for domestic energy security, global national security, nonproliferation, and nuclear materials management.

We are highly involved in a joint effort between Russian and American scientists to help policymakers and technical entrepreneurs understand the issues and opportunities posed by nuclear power. In the U.S., Sandia and a group of seven national labs reached out to bring energy and manufacturing companies into the vision, with a meeting and discussion of issues at mid-year. Later, laboratory directors from both Russia and the U.S. met in Vienna, Austria, to chart out a path to gain political and public support.

Nuclear safety

Sandia's blend of modeling, analytical, and experimental capabilities, combined with expertise in risk assessment for nuclear power plants has put us in a lead position in working with the NRC on a variety of projects. Sandia is using its knowledge of reactor safety to help DOE and industry

High-temperature reactors have greater efficiency with vastly reduced amounts of waste and lower risks of producing weapons-usable materials. Beneficial by-products of these reactors are the high-temperature production of hydrogen and the energy to desalinate water. Sandia is involved in programs to develop the capabilities to produce both hydrogen and desalinated water (see “Water initiative” page 67). Sandia is coordinating a multi-lab effort that will guide nuclear hydrogen



Sandia demonstrated a wireless instrumentation system, which couples power and data, allowing instrumentation of sealed containment vessels for nuclear materials. The power and data are coupled through the container walls via magnetic coupling between concentric coils inside and outside the canister. This technology supports the goal of ensuring safe transportation of nuclear materials and eliminating costly individual container inspections. Bench testing has demonstrated the feasibility of transferring energy and data through multiple walls of stainless steel and lead. Future development will require high temperature electronics to measure hydrogen content, pressure, and temperature,



Sandia manager Tom Sanders (right) confers with Sandia President C. Paul Robinson at an international meeting of Russian and U.S. laboratory directors, held in Vienna, Austria, to map out a path forward for promotion of safe and clean nuclear power around the globe.

Yucca Mountain is the proposed permanent repository for high-level radioactive wastes, including spent fuel rods from nuclear reactors. The site, mostly buried beneath this mountain, is 100 miles north and west of Las Vegas, Nevada.

Ron Price examines shards from a large block of Yucca Mountain volcanic rock tested for strength at his laboratory in Albuquerque.

His work provides critical information for developing design and performance standards for the repository.



and to add electronic identification to each containment vessel.

Waste legacy

While the 2004 political campaigns brought claims and counterclaims about the feasibility of the nation's first high-level waste and spent nuclear fuel geologic repository, research by Sandia engineers continued. Following a site recommendation from the Energy Secretary, approved by congress and the president in 2002, Sandia and other research institutions sharing scientific responsibilities at the site began the effort to assemble a license application to the NRC. Engineers at Yucca Mountain continue to press to meet a demanding schedule for repository data to satisfy the licensing process. High quality data and analysis are requisite for licensing success and public assurance. Sandia directly contributed to a monumental body of work with defensible analyses of site performance, for a decision of national importance affecting America's national and energy security.

Meanwhile, our participation in the DOE's Advanced Fuel Cycle Initiative is aimed at developing spent fuel treatment and transmutation technologies to enhance the performance of the proposed repository and reducing the costs of geologic disposal. Working with five other labs as integrator, Sandia is providing systems analysis for the program.

Sandia and Lockheed Martin Missile and Fire Control (LMMFC) in Orlando, Florida, forged the first-of-a-kind agreement with the government of the Republic of China (Taiwan) that makes a win-win situation for the three entities. Sandia will provide technology to Taiwan's geologic repository science program, thereby helping Taiwan maintain its nuclear power program and safely dispose of its spent nuclear fuel. LMMFC will fund Sandia's work and simultaneously earn credit toward Lockheed's contractual obligations to the Taiwanese government.